LIFE HISTORY AND MORTALITY OF THE LONGICORN *EPITHORA DORSALIS* MACLEAY (COLEOPTERA: CERAMBYCIDAE) IN TASMANIA

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Abstract
The life history and mortality factors regulating populations of the cerambycid *Epithora dorsalis* are recorded for Tasmania. The implications for the introduction of biological control agents against Australian cerambycids attacking eucalypts overseas are discussed.

Introduction
The longicorn *Epithora dorsalis* Macleay is a common wood boring beetle found in the dry sclerophyll forests of Tasmania, attacking many species of stressed or dying eucalypts.

There is little published information on the factors influencing mortality and population size of Australian cerambycids which attack eucalypts (Powell 1982; Moore 1963, 1972). However many cerambycid species whose larvae are subcortical zone feeders have parallel life histories, may share similar mortality factors and co-habit stressed trees (Bashford, unpublished data).

Several species of Australian longicorns, such as *Phoracantha semipunctata* (F.), have become important pests in overseas plantings of eucalypts particularly in southern Europe, South Africa and more recently in California (Hanks *et al.* 1993, Loyttyniemi 1980, Cadahia 1986, Drinkwater 1975). In some of these countries attempts are being made to introduce biological control agents from Australia (Drinkwater 1973). Lack of information on the species and distribution of these agents is an impediment to successful control being implemented.

The mortality factors that regulate *E. dorsalis* populations within their natural environment are examined in this study.

Methods
Sampling for *E.dorsalis* was conducted at Woodsdale 60 km east of Hobart (1:100,000 Little Swanport sheet EN 518 966). The study site was a pure stand of 63 year old *E. obliqua* L'Herit trees over a sparse understorey.

Twenty mature *E. obliqua* trees were felled in November 1984, some three weeks prior to the start of the known emergence period of *E. dorsalis*, and allowed to be naturally attacked. These trees were sampled on a regular basis over two years for host insects and natural enemies.

The timing of trap tree establishment was important in reducing attack by other cerambycids or woodboring insects. Most cerambycids at this site emerge in spring whilst *E.dorsalis* is a mid-summer emergent. During the log dissections all cerambycid larvae were identified and only *E. dorsalis* recorded for mortality factor analysis. The portions of trees remaining in the field in spring of the second year were not attractive to cambial feeding cerambycids.

The felled trees were placed on trestles with crowns retained to slow the rate of drying and to extend the period of tree attraction. The trees were divided into four groups of five trees. A different group was sampled each week, ensuring that all trees were sampled once a month.

A 50 cm length was cut alternately from the centre or the butt when sampling each tree. This enabled any effect on egg deposition or larval survival due to stem diameter or bark characteristics to be detected. Each individual log sample was measured for length and diameter under bark, so that surface area and log volume could be calculated. A 3 cm long disk was cut from one end of the sample for assessment of bark and heart wood moisture content. The 3 cm disks were debarked and both bark and heart wood weighed, oven dried and then reweighed.

Counts were made of egg batches laid on the bark surface then egg maturation and larval survival estimated by comparing egg counts with the number of early instar galleries. The sample logs were then debarked and life stages, predators and parasites counted. The debarked logs containing pupal tunnels were individually placed in wire mesh cages at ambient room temperature for emergence.

The pupae of parasitoids and larval hosts with dipterous larvae feeding on them were separately placed in petri dishes in an incubator at 18°C to monitor emergence. Predators were individually placed into petri dishes lined with filter paper with one or two live host larvae and reared in the incubator.

This programme of progressive sampling enabled an accurate assessment to be made of the duration of life stages of both *E. dorsalis* and associated insects. An analysis of mortality factors was then conducted using this data.

Results

Wood samples.

The mean diameter (DBHOB) and age of the 20 sample trees were 16.9±1.2 cm and 63±0.7 years respectively.

A total log length of 294.4 m was debarked and sampled during the study. A total surface area of 112.3 m^2 was examined for life stages and a log volume of 6.7 m^3 caged for adult emergence.

Life stages

(a) Egg deposition and survival

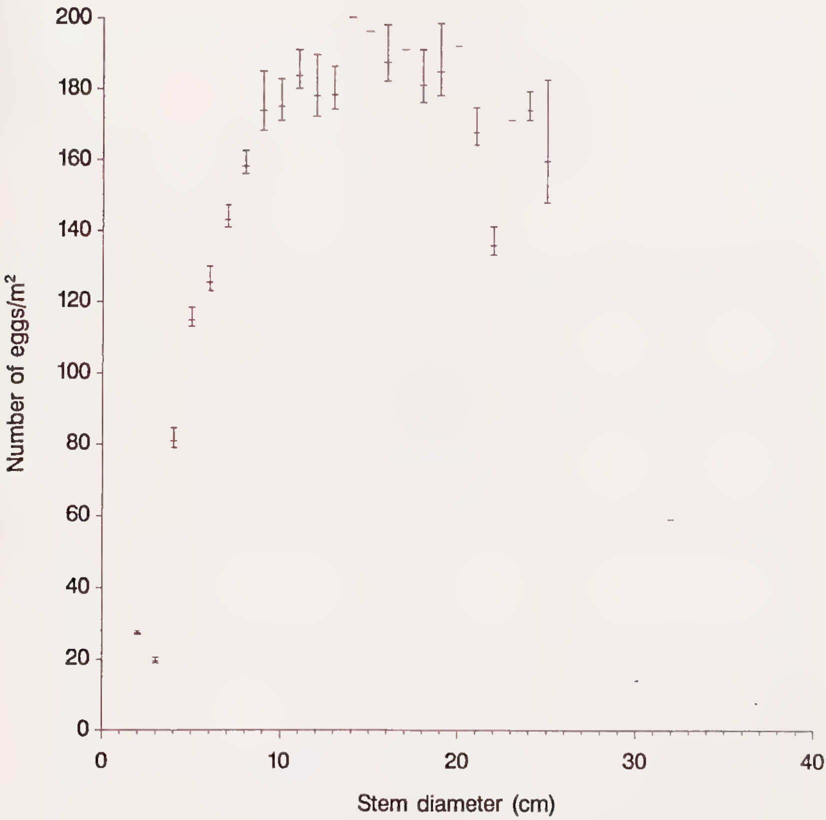

Fig. 1. Egg deposition by *Epithora dorsalis* in relation to stem diameter of *Eucalyptus obliqua*, (mean and SE, n=19).

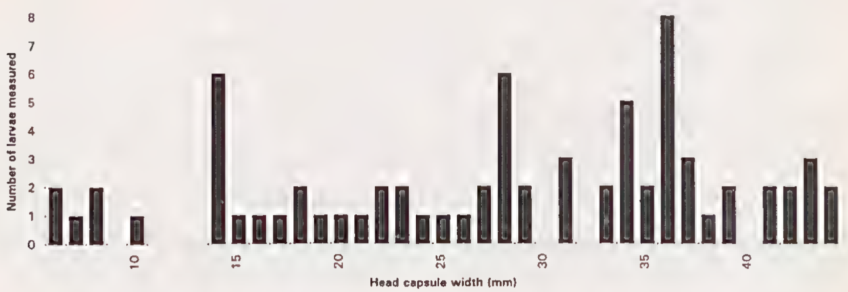

Fig. 2. Frequency distribution of head capsule witdths of *Epithora dorsalis*.

Egg counts were made from batches laid on the bark surface and further checks made by comparing those totals with initial gallery formation made by early instar larvae. During this study, parasitism, predation, or desiccation of eggs was not directly observed. A total of 17765 eggs were counted, averaging 888 per tree. Figure 1 shows the pattern of egg deposition in relation to stem diameter. Females showed a preference for oviposition sites on the lower half of the tree in areas where bark was less than 1 cm thick or in deep fissures. Newly hatched larvae were seldom able to penetrate thicker bark. Preference for rough fissured bark compared to smooth surfaces was a factor in successful egg survival. Egg batches were evenly deposited on upper and lower surfaces of the trestled trees with larvae migrating to the shaded undersurface as they developed.

Egg laying commenced 30-36 days after the trees were felled and continued to the end of March. Eggs held at 18°C and 70% RH hatched within three weeks (x=20 d, range 19-22 d, n=37 batches). The pale yellow eggs were laid in batches of 1-35 eggs (x=5±0.4, n=157) usually in bark fissures or the crotches of branches. The poles of the eggs darkened during development. The egg surface was covered with numerous short hairs making the surface 'sticky'. The spindle shaped eggs measured 2.3±0.05 mm in length and 0.8± 0.04 mm in diameter (n= 25).

Regression analysis of egg deposition against billet diameter showed a strong correlation (R = 0.82) with the basal 14 m of bole.

(b) Larval survival and development

Larvae hatching from eggs laid in bark fissures penetrated the bark horizontally to reach the subcortical layer where the larvae then radiated out from the common entry point forming a characteristic fan pattern.

The developing larvae fed for 10-43 weeks (x=32) in the cambial layer before forming pupation chambers in the heartwood. Of these 34.5% survived to final instar stage and commenced pupal chamber construction. Larval mortality factors to this stage included parasitism, predation, desiccation, fungal infection, and water logging of bark.

Individuals which completed their immature stages and emerged within one year passed through a minimum of five instars leaving exuvial remains embedded in frass filled galleries. Head capsule measurements are variable and do not separate into discrete groupings (Figure 2). However application of Dyar's law to the range of widths demonstrated a probable fit of six proportional growth increments of 8:11:15:21:29 and 41 mm (Dyar 1890).

Desiccation was the cause of at least 13% of larval mortality. Desiccated larvae were defined as being entire, often lightly shrivelled and hard. Desiccation was mainly due to bark drying then separating from the subcortical layer. Bark separation occurred several months after the trees were felled before the larvae were large enough to migrate to the shaded undersurface of the trunk. Bark separation also allowed the entry of free

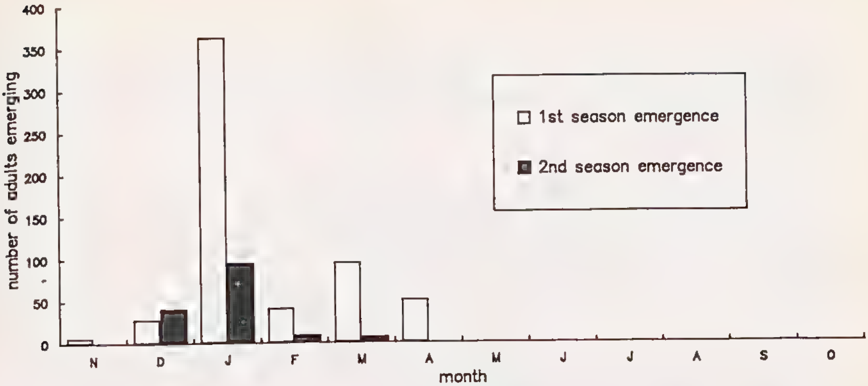

Fig. 3. Seasonal emergence of the cerambycid Epithora dorsalis in Tasmania

water to seep along tunnels causing mortality by drowning and by providing the climate for rapid fungal development.

The entomophagus fungus *Beauvaria bassiana* (Balsamo) caused high larval mortality during periods of high moisture content of bark and wood, or where overcrowding occurred. The extent of larval mortality caused by *B. bassiana* was impossible to accurately assess and was included in 'other causes'.

Attacks by the yellow-tailed black cockatoo *Calyptorhynchus funereus* during the winter months resulted in removal of 1% of large larvae and also caused mortality of adjacent larvae by exposure. Determination of cockatoo predation was based on empty larval chambers exposed by the birds habit of stripping bark away and splintering the underlying timber during the search for large larvae. Only the upper surface of logs on trestles were damaged in this way.

Predation by several species of clerid and elaterid beetle larvae (7.7%) and parasitism by tachinid flies and braconid wasps (3.6%) caused further mortality. The weekly sampling of billets enabled predators to be collected and reared. Predation in the life table is based on the number of predators collected and not on the number of hosts those predators may have consumed.

Up to 49% of final instar larvae died during construction of the pupal chamber or as pharate pupae.

(c) Pupation and emergence

After the pupal chamber was constructed an exit hole was cut in the bark, then the hole and gallery to the chamber sealed with sawdust. Four percent of individuals in sealed chambers died during ecdysis.

Emerging adults cleared the sawdust-filled gallery and flight hole, then often remained in the gallery for several days during inclement weather.

In this study approximately 12% of the initial egg population developed through to adult emergence over a two year period. Seventy eight percent of adults emerged within 12 months, the remainder emerging in the second year (Figure 3).

Adult behavior

Females mated on emergence and accepted multiple matings over a period of several days before ovipositing. Mating lasted 2 - 8 minutes, the female being passive and extruding the ovipositor.

The adults were very active on the bark of trees during the evenings and sheltering during the day in bark crevices. Newly emerged females were short lived even when supplied with water, which they drank avidly, surviving at 20°C for 5 -8 d. Males kept under the same conditions lived for 5 -14 d.

Life table

Construction of the life table was aided by the technique of regular sampling in the field which ensured that most mortality factors were not affected by storage in the insectary. The format used by Witter *et al* (1972) was adapted to accommodate the multi-mortality factors influencing survival in a restricted habitat. Table 1 lists the mortality factors, the actual mortality in numbers as a percentage of initial population, and the survival within each

Table 1. Life table for a single generation of *Epithora dorsalis* within *Eucalyptus obliqua* (means of 20 trees).

Life stage x	Number alive per tree lx	Mortality factor dxF	Number dead dx	dx as % of x 100qx	Survival of life stage Sx
Eggs	888	-	0	0	1.00
Larvae	888	Desiccation	114	12.80	0.87
		Clerids	28	3.15	0.97
		Elaterids	41	4.62	0.95
		Tachinids	2	0.23	0.99
		Braconids	32	3.60	0.96
		Cockatoos	8	0.90	0.99
		Other	357	40.20	0.59
Final instar larvae	306	Chamber construction	150	49.02	0.51
		Clerids	3	0.98	0.99
		Parasitism	46	15.03	0.85
Pupae	107	Ecdysis	4	3.74	0.96
Adults	103				
			786	88.51	0.11

Adapted from Witter *et al* (1972).

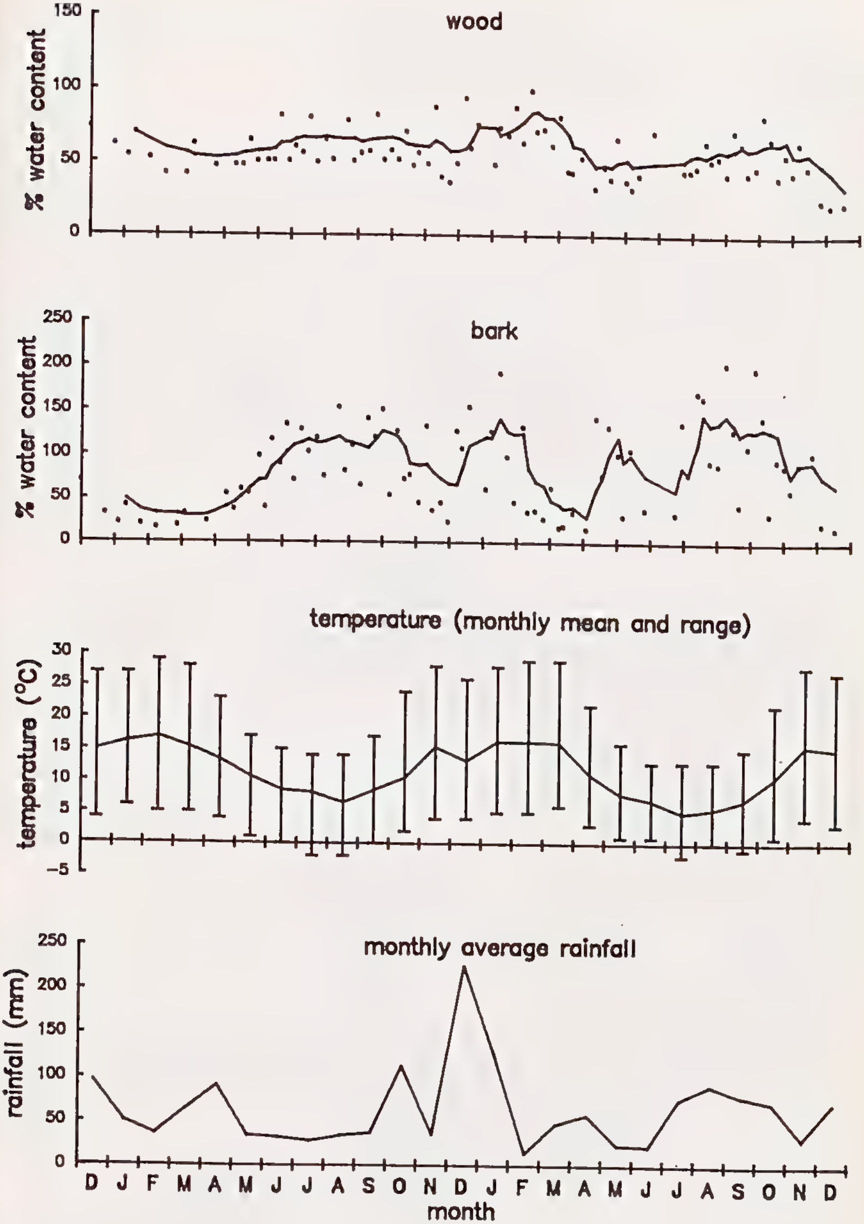

Fig. 4. Comparison of wood and bark moisture content with temperature and rainfall readings. Woodsdale.

life stage. A large proportion of larval mortality could not be assigned to specific causes. However, competition between larvae for food would be a limiting factor.

Moisture content of bark and wood

The rate of water loss (% moisture content) from both bark and heartwood was measured at each sampling period. Survival of larvae was dependant on a reduction of cambial moisture from 160% to 120%. Entry of larvae to the cambium resulted in rapid moisture content decline over 15 days to 100%. Once colonisation was established and bark separation occured then fluctuations in the bark water content became very variable being regulated by external weather conditions. Heartwood levels remained constant at 100% until pupal chamber construction occured then dropped over a ten day period to 60%. Following emergence of adult beetles a rapid decline of heartwood texture and density resulted in considerable fluctuations in water moisture levels. Figure 4 compares the moisture levels of bark and heartwood over time to meteorological conditions. There is clearly a relationship between increased variation in moisture content of bark during the period of longicorn larval development. However, heart wood retained a more constant moisture content level until pupation and emergence of adults then fluctuations became marked especially during periods of high rainfall. Prolonged high moisture levels under bark resulted in ideal conditions for *B. bassiana* development and increased mortality of larvae.

Predation and parasitism

Twenty species of parasitoids and predators were reared from logs containing *Epithora* larvae. One hyperparasitoid was present in low numbers.

Parasitoids	Number reared	
Hymenoptera	males	females
Braconidae		
Austrohelcon sp.	2	0
Doryctes sp.A	30	12
Doryctes sp.B	10	6
Doryctes sp.C	196	239
Gen. near *Doryctes*	11	17
Iphiaulax rubricepsis Shenefelt	19	5
Syngaster sp.? *lepidus* Brullé	40	23
Trichiohelcon phoracanthae (Froggatt)	2	5

Diptera	Individuals
Tachinidae	
(Tribe Dexiini)	
Platytainia maculata Macquart	40
Hyperparasitoid	
Hymenoptera	

Eurytomidae	
Eurytoma sp. near *descartisi* Ashmead	13
Predators	
Coleoptera	
Elateridae	
Agrypnus pictipennis (Candeze)	21
Agrypnus sp.	13
Toorongus jugulatus (Candeze)	5
Trogossitidae	
Lepidopteryx decorata (Erichson)	2
Lepidopteryx monilata (Pascoe)	7
Cleridae	
Blackburniella hilaris (Westwood)	6
Cylidrus nigrinus White	33
Eunatalis porcata (Fabricus)	41
Tenerus abbreviatus White	162
Gen. indet.	3
Colydiidae	
Deretaphrus piceus Pascoe	11

Observations on the parasitoids and predators

Parasitoids

Between 3-14 individual *Doryctes* spp. utilised a single cerambycid host. The pupal period for these parasites lasted three months during the early summer period and up to five months during the winter period.

Observations made during bark removal indicate that the larger parasitoid species, *Iphiaulax*, *Syngaster* and *Trichiohelcon*, all laid a single egg on the host and the larvae were solitary in occupation of a host. Subsequent egg deposition resulted in cannabalism by the first hatched parasitoid larva.

Adults of the tachinid parasite *Platytainia maculata*, were active throughout the summer months. Most longicorn host larvae contained a single tachinid but some larger hosts supported up to three tachinids which pupated successfully. Prior to this study the tachinid *P. maculata* was known only from a headless holotype in the Australian National Insect Collection (ANIC) (Barraclough, *pers. comm.*). A specimen of ?*Platytainia* sp.indet.was reared by Moore (1972) and thought to be the cause of death of a longicorn larva. A series of specimens of *P. maculata* have been lodged at ANIC.

The eurytomid hyperparasite *Eurytoma* sp. nr *descartisi* emerged from the pupae of *Syngaster* sp.? *lepidus*.

Predators

Elaterid and clerid larvae were common mortality agents and found in samples from all trees. The predatory larvae were placed singly in filter paper lined petri dishes and fed similar sized cerambycid larvae. Most larvae moulted soon after consuming a host and feeding continued for up to six months before pupation occurred. A one year life cycle was established for all the predators except *Eunatalis porcata*. This large clerid consumed up to 23 prey during a two year feeding period moulting five times. The late instar larva entered the cerambycid pupal chamber during construction. The host pre pupa or pupa was consumed, pupation occured in the host chamber and adults emerged in autumn through the cerambycid emergence tunnel. In a few cases *E. porcata* adults emerged three years after the log had been caged. The other clerid and elaterid species emerged during the summer months in the year of host emergence.

The colydiid *Deretaphrus piceus* was found only as pupae and although reared on cerambycid larvae by Moore (1963) the larvae could also be feeding on other predaceous larvae and parasite pupae.

Most of the elaterids and clerids in this study preferred to feed on cerambycid larvae but consumed parasite pupae when offered. *Agrypnus* spp. did feed on *Iphiaulax rubricepsis* pupae when very hungry but on other occasions died without attacking offered pupae.

Other insects reared from billets

Four species of cerambycids were reared from log billets. Numbers of specimens are in brackets. *Coptocercus rubripes* (Boisduval) (36 specimens), *Tessaromma sericans* (Erichson) (28), *Tessaromma undatum* Newman (7) and *Callidiopis scutellaris* (Fabricius) (11). The bostrichid *Xylion collaris* Erichson and its associated predator *Paratillus carus* (Newman) emerged in large numbers in both years.

Mites

Mites were found on most adult *E. dorsalis* emerging in the second year but were seldom seen on first year emergents. Aggregations of 3-60 mites were found situated mainly between the legs on the mesosternum. The large brown mites did not appear to have any adverse effects on mating or longevity of infested adults.

Discussion

In this study the pattern of early cambial drying with slower heartwood moisture reduction was similar to work reported by Chafe (1986) who measured the decrease in water content of both felled and standing *Eucalyptus regnans* trees in Victoria and found there was no difference in the rate of drying between the two groups of trees. The use of trestles to support freshly felled trees would not appear to effect the rate of drying or the attractiveness of the tree surface to ovipositing cerambycids. The correlation between egg deposition by *E. dorsalis* and stem diameter most likely reflects availability of suitable oviposition sites per surface area rather than tree height. The technique described provides a simple method for the determination of mortality factors or the collection of control agents.

Placement of trees is reliant on prior knowledge of the primary insect flight period so that infestation by other woodborers is reduced.

In most life-history studies of cerambycids,the major mortality factors have not been determined (Moore 1963, Powell 1982, Togashi 1990). In this study the technique of field sampling and subsequent insectary rearing enabled the mortality factors for *E. dorsalis* to be better defined with a low level of unknown mortality. Causes of mortality which could not be quantitatively measured, were determined and included *B. bassiana* infections, water saturation of bark, and competition between larvae. These factors account for almost 40% of early larval mortality.

Parasites and predators accounted for only 12% of larval mortality which indicates that the introduction of natural enemies to control populations of cerambycids with cambial feeding larvae is unlikely to be effective unless the relationship of these agents to each other is established. However knowledge of the feeding behavior of predators (ie.the number of hosts required to complete life cycle) is an area requiring investigation. If the assumption that the larger clerids and elaterids require to consume at least one host before moulting (Murray 1973) then the combined dx in this study would be 43.8% of all larvae rather than 8.8% calculated for one host. The introduction of Australian parasitoids overseas has not been attempted except in South Africa where the braconid larval parasitoid *Syngaster lepidus* was released to control *Phoracantha* species but did not become established (Drinkwater 1973). The number of parasites and predators reared in this study of *E. dorsalis* suggests that range of control agents against subcortical cerambycid feeders is considerable. Selection of a combination of agents particularly predators, could be effective in reducing damage by Australian cerambycids overseas.

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